Long-term ecological research in Australia: innovative approaches for future benefits

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ABSTRACT

PPBio (Program for Planned Biodiversity and Ecosystem Research) is a system for long-term ecological research designed to answer integrated multidisciplinary research questions. The system is based on permanent plots (terrestrial and aquatic) that are systematically spaced in grids (e.g. 5 km x 5 km) and modules (e.g. 5 km x 1 km) within a hierarchical long-term ecological research (LTER) network. Modules and grids sample biodiversity and biophysical variation in an unbiased manner across the landscape. Infrastructure includes permanent plots that follow contour lines (survey lines with all measurements recorded on the horizontal plane) which facilitates orthorectification and validation of satellite imagery. All research data and accompanying metadata collected are stored and are publicly available to facilitate ongoing integrated multidisciplinary research at local, meso, landscape and global scales. The PPBio system was designed to overcome the problems of idiosyncratic designs and incompatible data arising from 'stand alone' research projects, which are difficult to integrate or continue through time. The sampling design and data sharing arrangements are structured so that PPBio sites serve as hubs for research, building long-term datasets that integrate studies within and among sites, providing the information necessary to understand and respond to complex and dynamic environmental issues.

Key words: Biodiversity Monitoring, Condition Assessment, LTER, ILTER, data management, natural resource management, long-term ecological research

Biodiversity monitoring and the need for long-term ecological research

Land managers in Australia and across the globe face many challenges in responding to complex and dynamic ecological phenomena. Effective management of natural resources is dependent on robust scientific information, with long-term data being particularly valuable in understanding how ecosystems respond to events such as climate change or management interventions (Hughes 2000; Stork *et al* 1996).

Nations across the globe grapple with the challenge of meeting the 2010 Convention on Biological Diversity targets for conservation and sustainable use, but attainment of these goals is underpinned by assessments of baseline conditions (inventories) and trends in these conditions (monitoring) (Stork *et al* 1996). There is little doubt that biological research and monitoring is an important scientific activity that will enable scientists and managers to review the impacts of both natural and anthropogenic impacts on our natural environments facilitating a reporting on the state of the environment (e.g. Beeton *et al* 2006). However, the manner in which such monitoring should be undertaken remains a vigorous point of discussion (Purvis and Hector 2000; Yoccoz *et al* 2001; Nielsen *et al* 2007).

In response to the need for nationwide measures of biodiversity a number of countries have developed large scale monitoring initiatives (see reviews by Wiser *et al* 2001; Craine *et al* 2007) with some building on historical data archives (e.g. Wiser *et al* 2001) and others developing strategies that encompass entire countries (e.g. Lane 1997, Swiss Biodiversity Monitoring Programme; Hintermann *et al* 2002). Perhaps the most well known of these approaches is the LTER program, initiated by the National Science Foundation in the USA in the late 1970's (Callahan 1984, Hobbie *et al* 2003), aimed at addressing the need for long-term studies addressing large scale issues. Global interest in the need for long-term research prompted the establishment of an international network of sites for long-term ecological research (ILTER). At present 37 counties have established LTER networks as part of this global initiative and Australia is included as one of these participating nations (see http://www.ilternet.edu). However, the manner in which these ILTER networks are managed and the level of coordination among the sites is highly variable. For example the Environmental Change Network (ECN) in the United Kingdom has established a series of 12 terrestrial and 45 freshwater sites. At each of these sites a series of standardised data is collected to build up a national database for environmental monitoring and reporting. Conversely, Australia has only 5 sites listed in a small informal network (see http://www.daff.gov.au/brs/

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forest-veg/research-sites) which presents considerable deficiencies in providing information critical for efficient environmental reporting across Australia. This shortcoming within the Australian network requires urgent attention and we suggest that the approach outlined in this paper presents a potential solution to this. The need for a more strategic view of long-term ecological research and monitoring is not restricted to Australia and we include examples from Brazil to demonstrate how these long-term objectives can be met.

We believe that there are three key strategies to increasing the efficacy of long-term research and monitoring programs. Firstly, we need to establish improved linkages between science and management in a systems approach that enhances sustainable resource management (Bosch *et al* 2003). Secondly, research and monitoring needs to occur over long temporal scales to enable the detection of trends in condition which are independent of any human interventions. Thirdly, a combination of structural and functional ecosystem components must be monitored to discern environmental trends. For example, the Environmental Change Network in the United Kingdom has used indicator groups (e.g. butterflies, moths and beetles) to monitor changes in biodiversity in response to climate change (DEFRA 2003). Such long-term ecological data are necessary for natural resource management actions, such as condition assessment, impact assessment, population estimation, planning and modelling, and are dependent on the rapid dissemination of the monitoring information to a multitude of stakeholders.

Long-term ecological data collection and use provides the foundation of ecological research and understanding, yet it remains an area characterised by minimal resources, *ad hoc* planning and is captive to short-term thinking. Despite the imperative for long-term ecological data, shortcomings in this information are increasingly being highlighted within Australia (e.g. NLWRA 2002; Productivity Commission 2004) and globally (e.g. Pereira and Cooper 2006). The National Land and Water Resources Audit's (NLWRA) Australian biodiversity assessment concluded that "a strategic and systematic approach to monitoring and reporting on Australia's terrestrial biodiversity requires a strategic analysis of the existing database in order to define and clarify information needs and link to other datasets" (p.186) to balance demands on natural resources. However, despite a number of subsequent reviews commissioned by the NLWRA (2004a; 2004b) these analyses are mostly focussed on continuous map coverage and remotely sensed imagery of a region to map vegetation patterns, rather than site-based data which provide direct measures of change. These site specific measures of change are critical to developing an understanding of the trends in condition as remote methods are frequently incompatible (Pereira and Cooper 2006) and are also prone to classification and interpretation errors (Thackway *et al* 2007).

Complimentary long-term ecological research: speaking from the same ecological page

The use of long-term ecological research sites to monitor changes in biological condition at local, regional and global scales is appropriately argued (Hobbie *et al* 2003; Parr *et al* 2003) but considerable debate remains as to the appropriate measures of such biodiversity within such networks. This symptomatic need for appropriate indicators from long-term ecological research sites is demonstrated by the variation in vegetation condition assessment metrics within Australia. A number of Australian States have developed condition assessment approaches to evaluate broadscale trends in biodiversity condition. The first, and most well known, of these is the Victorian 'Habitat Hectares' approach which is founded upon comparisons between existing vegetation and benchmark sites of the same ecological community in a mature and undisturbed state. A suite of ten habitat attributes are used to prioritise conservation interventions (Parkes *et al* 2003; McCarthy *et al* 2004). Similar approaches are being developed and applied in other States, such as 'BioCondition' in Queensland (Eyre *et al* 2006) and 'BioMetric' in New South Wales (Gibbons *et al* 2005). Criticism is increasingly being directed at these approaches with regard to perceived errors, inconsistencies and lack of detail. Resolution of such problems is hampered by inadequate spatial and temporal data. A well planned network of long-term research sites across the landscape would be an invaluable asset to assessing, comparing and refining the multitude of condition assessment approaches at such sites over time. Biodiversity condition, and the ecological data that underpins it, are also assuming increased importance within the Australian Government (e.g. DEH 2005). Understanding and tracking these changes in ecological condition and understanding the key influences will be very important, particularly in establishing ecosystem thresholds, deciding when management interventions are justified, monitoring changes resulting from management activities, and the legal enforcement of such actions.

Long-term ecological research sites are necessary to understand and manage ecosystems and Westoby (1991) has urged greater cooperation and research funding incentives to establish and maintain such sites across Australia. Numerous Australian organisations have (or have had) such sites used for many purposes such as fire management, forestry monitoring (e.g. EPA 1999), grazing (e.g. Sinclair 2005) and biodiversity monitoring (e.g. Neldner *et al* 2004), which could potentially be exploited for broader ecological research. However, the question-specific design, poor awareness, and the limitations of data and sampling methodologies, often limit the wider use of such datasets. For example, such site-based sampling can often have inadequate replication to statistically examine patterns or trends across the landscape (Lawson *et al* 2007). As a result these isolated sites are poorly comparable and do not therefore contribute to our understanding of ecological processes. Gioia's (2005) assessment of information management in State and Commonwealth conservation agencies concluded that these "sites of significance" were of "high strategic significance" (p.27) to biodiversity information systems. He recommended clear identification of these sites and a description of their purposes and attributes (e.g. managed research plot, long-term monitoring) within database systems as vital to their effectiveness. Such a database would be a highly useful starting point for a fundamental reconsideration and restructure of how we collect and use ecological data. In addition, a parallel process of metadata enhancement is needed to enable an assessment of data compatibility and complementarity.

Given the variation in such sites between agencies and States, and the imperative for cost effective use of survey resources (Burbidge 1991; Gardner *et al* 2008), there exists a need for an audit of these sites to understand their characteristics and to maximise their utility for ecological understanding. Such audits have been undertaken in other countries to provide the basis of long-term ecological research (Chapman and Busby 1994). Analysis from the Eden region of southern NSW showed some analyses were not sensitive to variations in sample size between 0.04 and 0.1 hectare (Keith and Bedward 1998), suggesting that there is some scope for useful comparison and analysis of sites with varied collection methods, albeit with appropriate checking of data comparability. Any review should include sites established for a variety of purposes to determine the suitability of their information.

Across the globe many long-term monitoring programs have been initiated (Wiser *et al* 2001; Craine *et al* 2007) although not all of these are affiliated to the ILTER network. Many of these are in regions recognised for their high biodiversity but much of this is relatively poorly understood (e.g. Amazonia in Brazil, Magnusson *et al* 2008). Many studies have focused on a limited range of taxa, or only abiotic processes, and have widely differing sampling methods which limit their comparability. In some cases, the logistics entailed in regularly resurveying the sites inhibits their wider application (e.g. Tropical Forest Census Plots, Condit 1995, 1998, Magnusson *et al* 2008).

These challenges have prompted a review of the approaches to long-term ecological research and monitoring (Strayer *et al* 1986, Ferraz *et al* 2008) facilitating the development of new approaches such as the Program for Planned Biodiversity Ecosystem Research in Brazil (see reviews by Magnusson *et al* 2005, 2008). Faced with the challenges of ensuring that long-term ecological research should contribute to biodiversity conservation in a coordinated manner, we will outline options for how such long-term ecological research could be achieved in Australia.

Advancing long-term ecological research and monitoring within Australia

Site-based ecological data has many possible applications, the scope of which is dependent upon the quality and range of information recorded (Neldner *et al* 2004). However, these site based approaches have a number of shortcomings and Ferrier (1997) summarised data gaps into three categories, and provides the reasons for them:

- geographical gaps: only a portion of a region can realistically ever be sampled.
- temporal gaps: one-off and short duration surveys don't adequately describe temporal change.
- taxonomic gaps - not all biodiversity elements are sampled each time.

Burbidge (1991) has concluded that the paucity of basic information on the distribution of most taxa across Australia necessitates well-designed surveys serving multiple objectives to achieve scientifically sound nature conservation surveys in a cost-effective manner. The need for these baseline assessments is reiterated not only by the scientific community but also by managers. Worboys (2007a) assessed the responses by protected area and natural resource managers and found that there was an overwhelming need for assessing management performance in response to established baselines. These contextual baseline conditions (fauna, flora, habitats, ecosystems etc.) are critical for benchmarking and inclusion in the adaptive management process (Worboys 2007a). How then can this be implemented within Australia?

We believe that the implementation of a national biodiversity research and monitoring strategy for Australia is both achievable and imperative given the emerging national environmental challenges. There are however, a number of key steps to ensuring that such a system is able to deliver on its objectives. Firstly, the network design has to be flexible to support a multi-scalar approach. Using a multi-scalar approach caters for the scalar variability of environmental structure and function across the landscape and ensures the network can monitor biodiversity at local (site), regional (landscape) and national (biome) scales in a nested hierarchy. Secondly, the selection of monitoring indicators needs to be centred on a core set of variables that provide the basic baseline data which can be supplemented as necessary with site-specific requirements to cover emerging research priorities. The selection of indicator taxa that enable cost-effective monitoring has been strongly argued and vascular plants, birds and dung beetles are frequently identified as being of high value (Pereira and Cooper 2006; Gardner *et al* 2008) but Lindenmayer *et al* (2001) urge a cautionary approach and suggest that structure-based indicators may be more appropriate than taxon based indicators in areas where our taxonomic knowledge is limited. Thirdly, the survey methodologies should allow for comparable assessment of biodiversity indicators across a range of spatio-temporal scales. This is critical to enable the accurate detection of trends in condition while also being able to differentiate between trends in response to anthropogenic versus natural drivers. Lastly, data generated from such monitoring need to be housed in a central widely accessible location where both scientists and land managers can access these data in a short time frame to facilitate adaptive management practices that build from the learning experiences arising from the long-term monitoring.

One approach that is able to meet the requirements of an efficient long-term ecological research and monitoring strategy across Australia, is the RAPELD approach to standardised surveys (rapid assessment surveys at long-term ecological research sites) used by the Program for Planned Biodiversity and Ecosystem Research (PPBio) developed in Brazil (see Magnusson *et al* 2005). Similar to Australia, Brazil is geographically a large country, has high biotic diversity and heterogeneity, and limited resources for monitoring. RAPELD is a universal meso-scale (> 100ha spatial extent or >1:25,000 spatial resolution, as per Ferrari & Ferrarini 2008), multidisciplinary system designed for cost-effective and efficient ecological research and data collection. It provides a new model for biodiversity research, monitoring and assessment that can be replicated throughout Australasia, providing an innovative foundation for enhancing environmental management and monitoring the impacts of climate change in the future. The approach is designed to overcome present restrictions facing site-based ecological data collection which are characterised by *ad hoc* implementation and analysis, single purpose aims, duplication and wasted resources, which ultimately result in non-comparable data of limited ecological value. As such, the PPBio program is one of the few means of achieving these universally relevant aims in a cost-effective framework for ecological research and management, with the potential to also monitor social, political and economic issues and their interactions with environmental systems. Although some existing systems are adequate for some taxa, or particular questions, most are inadequate for the needs of most users (conservation planning, environmental impact assessment, bio-prospecting, monitoring of harvesting, environmental reporting etc.). We suggest that the establishment of a network of long-term ecological research sites along ecological gradients in Australia using the PPBio approach would improve the ability of scientists and managers to report on and respond to environmental changes, most notably the effects of climate change.

PPBio aims to assist agencies and land managers in collecting long-term data on biodiversity and ecosystem assessment on public and private lands. The program includes a number of important components:

1. The system is based on permanent plots (terrestrial, aquatic or marine) that are systematically spaced in grids (e.g. 5 km x 5 km) and modules (e.g. 5 km x 1 km) within a hierarchical long-term ecological research (LTER) network (Magnusson *et al* 2005, Mendonca *et al* 2005). This meso-scale approach facilitates the compilation of replicated sampling of local biodiversity and biophysical data but importantly enables the integration of these replicate plots to improve our understanding of biodiversity patterns across broader scales.

2. The RAPELD system is modular in its design and although core grids within the network should adhere to the 5km x 5km design, smaller site-specific modules (e.g. 5 km x 1 km) of both trails and plots can be used to capture specific biodiversity features, experimental treatments, or to sample large areas cost effectively (Magnusson *et al* 2005).

3. All data collected in the plots will be publicly available on a dedicated internet site (owned by consortium members) together with the associated metadata so that they are available to land managers and other scientists. Data collectors have a two year window to publish results before their data are released. This ensures that these data are rapidly available to inform adaptive management responses, while accommodating the publication needs of researchers.

The strength of the PPBio approach is that it facilitates long-term ecological monitoring of key biotic and abiotic variables, while serving as a hub for dynamic and diverse ecological research responding to emerging priorities (Magnusson *et al* 2008). The international network of long-term ecological research sites focus multi-disciplinary research on biodiversity and ecosystem processes that allow managers to monitor both the local impacts associated with local management practices, and the long-term changes associated with global climate change.

The implementation of the PPBio approach is underpinned by a robust sampling design that can be replicated in any number of ecosystems at a global scale. This makes the PPBio approach well suited to the Australian situation. The RAPELD design has seven basic standards for such ecological surveys, as outlined by the Brazilian Ministry of Science and Technology (2006):

1. The use of standardised survey methods.
2. The use of integrated multidisciplinary surveys of all taxa.
3. The use of an area of a sufficiently large size to monitor all taxa and ecosystem processes (terrestrial, aquatic and marine).
4. The use of a modular design, to allow comparisons with samples taken over larger areas.
5. The compatibility with existing programs.
6. The ability to be implemented using existing resources.
7. The timely availability of useable data to managers and other stakeholders.

These standards underpin the success of the PPBio model.

Adopting the PPBio model within Australia

Australian biodiversity conservation and management currently lacks any consolidated approach to monitoring and reporting the condition and trend in condition of environmental variables. This is clearly indicated by the most recent Australian State of the Environment (SoE) report finding that 63% of SoE reporting indicators had no or inadequate data to base assessments upon (Beeton *et al* 2006). Existing SoE reporting is focused on a broad scale assessment of a number of indicators to report on trends over five year intervals (Saunders *et al* 1998; ANZECC 2000) and demands rigorous scientific monitoring to support these broad assessments. An inability to provide accurate reports on biodiversity condition is fuelled by the paucity of comparable long-term studies (Westoby 1991; Hahs 2001; Hughes 2003) demonstrated by Lunt (2002) who outlines the shortcomings of long-term vegetation change monitoring across Australia. Few long-term experimental studies exist and long-term changes are derived from comparisons of independent short-term studies prompting the need for initiatives that are able to establish baselines for various ecosystems and their constituent fauna and flora (Hughes 2003).

We believe that the PPBio approach can support existing SoE reporting mechanisms through the provision of long-term landscape-level monitoring data across a network of permanently marked sites stratified across broad vegetation types (see Magnusson *et al* 2005). These sites will incorporate a standard suite of 'core' biotic and abiotic data, each resampled regularly at time frames appropriate to each variable, to allow spatial and temporal comparison within and between sites (Magnusson *et al* 2005; 2008). This would provide baseline information for ongoing information on temporal change, and for additional ecological research at the site. A range of ecological research could be focused in and around such sites, with the aim of providing information for a range of purposes including linkage with remote sensed imagery, vegetation mapping, condition assessment approaches, ecological modelling, etc.

Given adequate cooperation, 'core' data would be freely available to other ecological researchers using the sites with the aims of decreasing duplication and improving information cost-effectiveness. Historically the limited budgets available to conservation science have limited the availability of biodiversity data (Balmford and Whitten 2003) as a result of surveys being targeted to specific indicator or surrogate species. The implementation of a truly integrated multidisciplinary approach that fosters the involvement of a diverse array of scientists is expected to reduce monitoring costs as these are absorbed within individual institutions. However despite the diversity of interests and expertise potentially contributing to data generation from the RAPELD grids these data will be comparable as a result of the standardised nature of the sampling protocols. The principles outlined above support Westoby's (1991) call for greater cooperation and research funding incentives to establish and maintain such sites.

Establishing PPBio - RAPELD long-term ecological research sites within Australasia

The PPBio Australasia program is coordinated by the Environmental Futures Centre at Griffith University and is focussed on the following:

- Establishing a network of long-term ecological research sites, that form part of the AusLTER and ILTER networks, and are available as a tool for resource managers and scientists globally. These sites contribute to providing the necessary data to inform future environmental management requirements in the face of climate change. There may be a number of more focused research objectives linked to particular sites however the need for such rigorously defined objectives is currently under discussion (Strayer *et al* 1986, Ferraz *et al* 2008, Magnusson *et al* 2008).
- Initiating long-term ecological research sites using RAPELD designs, with permanently marked survey plots (now established at: Karawatha Forest Park in Brisbane, Qld; Lake Broadwater Conservation Park outside Dalby, Qld; and Chitwan National Park (Nepal).
- Coordination of baseline biodiversity assessments at these sites using vegetation surveys as a core component.
- Developing appropriate experimental designs for collaborative projects, and compiling standardised survey methodology for monitoring abiotic and biotic indices of biodiversity.
- Providing internet access and database management support facilitating the storage and dissemination of data from a central location.
- Assisting with the analysis and interpretation of data collected.

Establishing a network of Long-term Ecological Research Sites

PPBio Australasia follows the RAPELD grid and plot design (described above, and in Magnusson *et al* 2005; 2008) and has initiated the establishment of these grids at two locations in Queensland and one in Nepal. The first key step is the position of the grid within the landscape of interest. This is undertaken in a consultative manner between scientists and natural resource managers, generally seeking to sample the longitudinal, latitudinal and altitudinal gradients with attention to threatened species or ecosystems. The actual grid position on the site is determined using GIS mapping overlays, with the positioning of the grid maximising the number of plots and avoiding any large infrastructure such as roads and or buildings (Figure 1). Additionally or alternatively, modules (grids smaller than 5 x 5 km, with smaller numbers of plots) can be used to incorporate additional habitats or land uses if required (e.g. vegetation types, corridors or areas under specific management regimes), or to obtain representative coverage of larger areas. The grid is preferably marked as a system of trails (Magnusson *et al* 2005), or virtual trails (followed by researchers using a GPS and/or compass).

Standardised RAPELD plots are generally placed at 1km intervals, evenly distributed along the 5 x 5 km grid (Magnusson *et al* 2005). Individual plots start midway between trail intersections (Figure 2). The 1km spacing is designed to promote independence of data between plot locations although grids with smaller intervals are possible and can be used to test for spatial independence among plots but also finer scale ecological processes. Each 250m plot midline is permanently marked with a metal stake every 10m (Figure 3a). Trees closest to the start and finish of the midline are marked with 2 thin bands of clear reflective paint (Figure 3b) while trees within 2m of the permanent stakes are marked with a single thin band

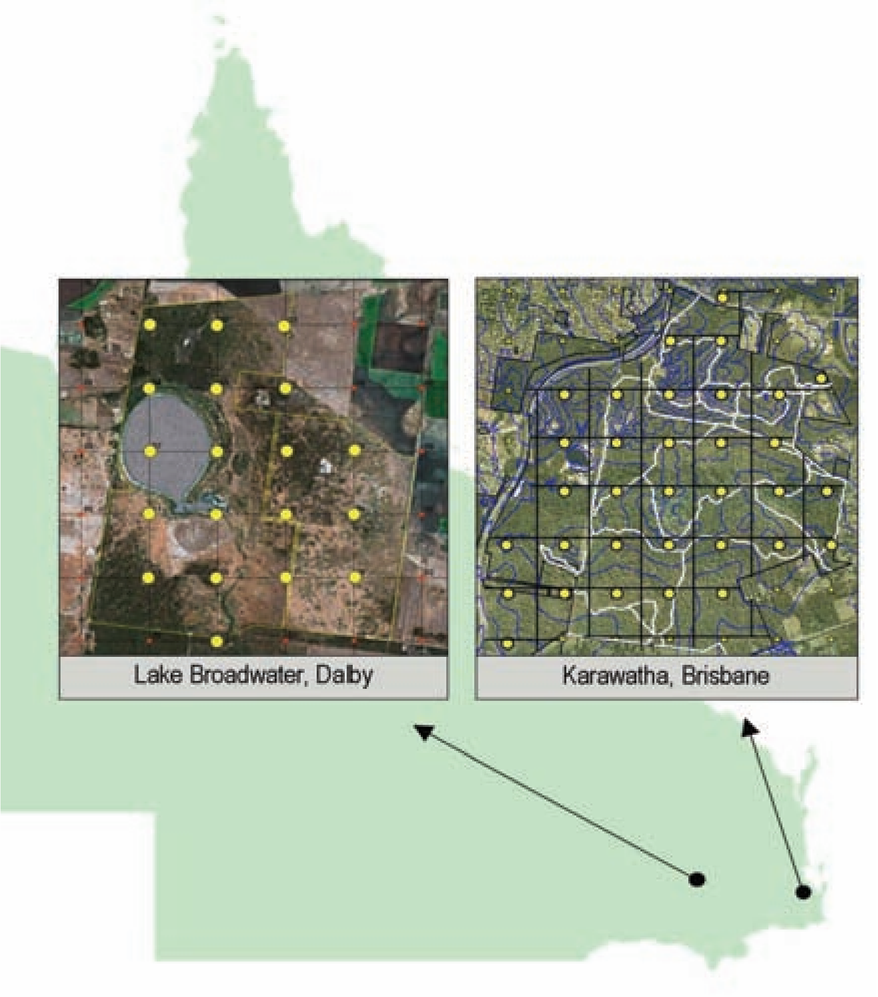

Figure 1. Location and layout of PPBio RAPELD grids established in Queensland at Lake Broadwater (Dalby Shire), with 19 plots at 1km intervals, and at Karawatha Forest Park (Brisbane City) with 33 plots at 500m intervals. Plots are represented by yellow circles.

(Figure 3c). Clear reflective paint is a subtle indicator of the plot locations that is barely visible during daylight hours but facilitates nocturnal research activities. Plot midlines and stake positions are recorded at 50m intervals along the midline using a handheld GPS.

Plot midlines follow topographical contours such that all the permanent markers are at the same altitude. The starting direction for each transect is arbitrarily determined to be in an easterly or westerly direction (depending on the position of the grid in relation to anthropogenic disturbances). Each centre line is a series of straight 10m sections (Figure 4) with the position of each stake accurately determined by using a laser level and a 10m chain. If the transect bisects a road (or any other anthropogenic disturbance) it is stopped and restarted on the other side of the road with a 10m buffer zone on either side of the disturbance. This plot design minimises within plot altitudinal, edaphic, topographic, and plant structure and composition variability (Costa *et al* 2005) and facilitates orthorectification and validation of satellite imagery, such as digital elevation modelling (SRTM) and forest structure assessment (LIDAR). Aspect is measured by taking a compass bearing looking down the slope, while slope is measured with a clinometer along a 5m strip centred on the midline and perpendicular to the elevation contour.

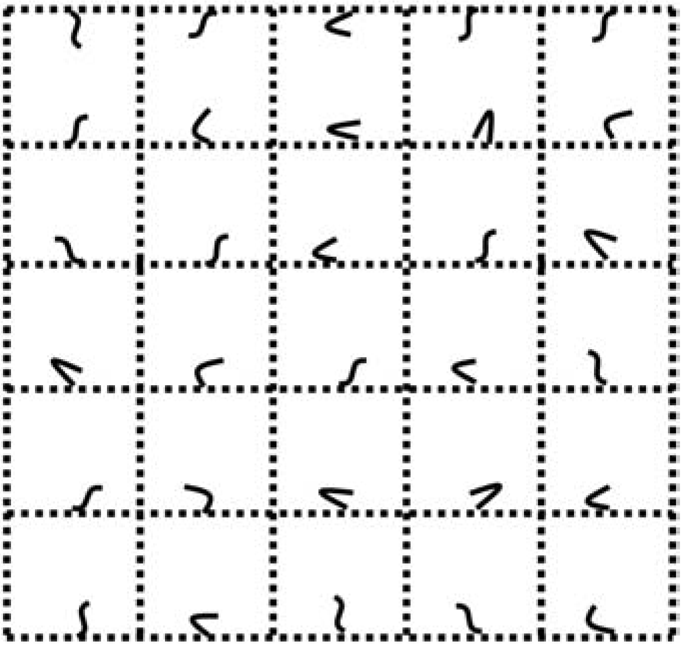

Figure 2. Illustration of the standard PPBio RAPELD grid system with plot midlines shown to follow contours between a 1km by 1km system of walking trail.

Data Collection and Biodiversity Monitoring

This section focuses on the value of the PPBio network of RAPELD grids as long-term ecological research sites for monitoring biodiversity and ecosystem processes; however these sites are also able to facilitate integrated studies from other disciplines including socio-economic analyses. One of the strengths of the approach is that it enables managers to relate biodiversity management issues directly with associated socio-economic constraints. Any number of biodiversity or biophysical variables may be recorded on each plot within a grid, only limited by funding and scientific resources. Standard measures during plot establishment include aspect and slope recorded every 50m along the midline (6 measures per plot) and summarised as plot averages.

Plot width varies to suit the taxon or abiotic variable being examined. Small and/or numerous taxa are surveyed in narrow plots (e.g. reptiles or herbs and grasses are within a 2m strip on one side of the midline) while wide plots are used for larger or more dispersed organisms (e.g. large trees or small mammals). Low density species and additional environmental variables are monitored using the larger series of grid trails (e.g. hollow trees, large mammals) using standard distance sampling methodologies and determination of detection functions for specific taxa (Buckland *et al* 1993, 2004) which will be a function of vegetation density.

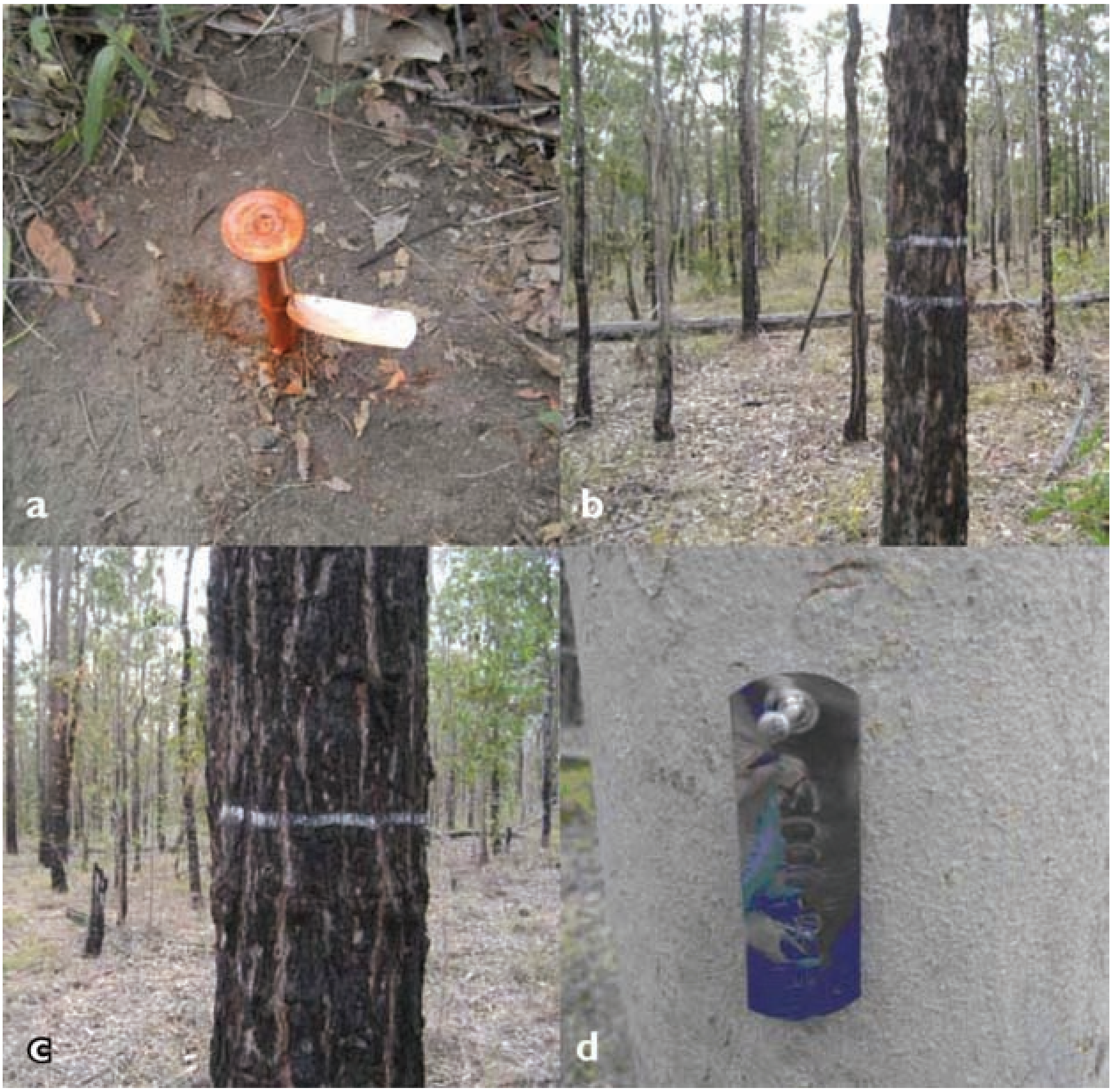

Figure 3. (a) Example of a tagged metal stake used to identify the location of the 10m intervals along the plot midline. (b) Marking of trees to identify the start and end of the 250m plot midline. The tree nearest to the starting point is marked with a double ring, (c) The tree nearest to each 10m peg along the midline. Trees are marked using reflective paint that is discreetly visible during daylight hours and facilitates nocturnal research activities, and (d) Example of an aluminium tag used to mark individual trees over 1cm DBH and placed at 140cm above ground level.

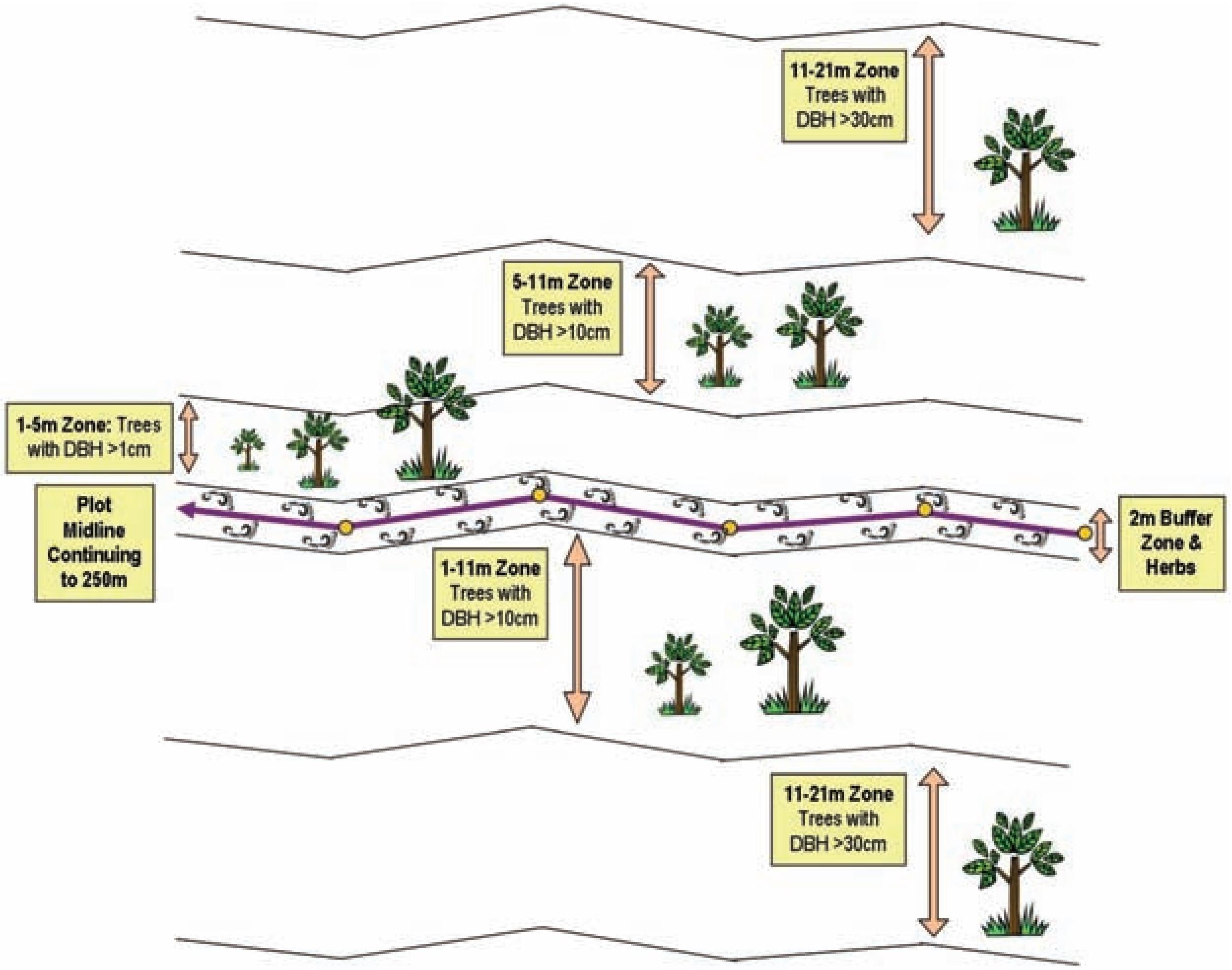
11-21m Zone Trees with DBH >30cm
5-11m Zone Trees with DBH >10cm
1-5m Zone: Trees with DBH >1cm
Plot Midline Continuing to 250m
1-11m Zone Trees with DBH >10cm
2m Buffer Zone & Herbs
11-21m Zone Trees with DBH >30cm

Figure 4. Illustration of the RAPELD plot design. The midline is marked with metal stakes at 10m intervals (represented by yellow circles). Lines represent variable width of the plot in response to the size (DBH for vegetation) and or density of the organism being measured.

One of the core variables for monitoring of the PPBio grids is vegetation condition. As part of the initial setup at Karawatha, we individually tagged (Figure 3d), identified, measured (DBH at 1.3m), and mapped (distance along the plot midline and perpendicular distance away from the plot midline) all woody stems (trees and shrubs) with DBH>1 cm within plots. A hierarchical design was used to sample trees of different size classes in order to estimate tree density in each plot (Figure 4). Large trees (DBH ≥ 30cm) were sampled to 20m either side of the midline (40m x 250m ≈ 1ha). Trees with DBH ≥10cm were sampled within 10m either side of the midline (20m x 250m ≈ 0.5ha). Trees with DBH ≥1cm were sampled along a 4m strip on the RHS of the midline (4m x 250m ≈ 0.1ha). Each plot varies slightly in area because of differences in the midline trajectory (which follows the contour line), and the area is calculated in a GIS program using the appropriate buffer width. To minimise trampling disturbance resulting from accessing the plots within the grid, a 2m buffer strip is retained along the plot midline (1m on either side).

Storage and dissemination of data

All data collected during surveys will be publicly available on a dedicated internet site (http://www.griffith.edu.au/ppbio) together with the associated metadata, for use by land managers and other scientists alike. Data owners are required to present their metadata at the start of their projects to enable others to replicate protocols at additional sites if necessary, and may take advantage of a two year window to publish results before these data are released to the wider scientific community. This protocol aims to avoid the loss of plot data through poor record keeping and/or the hoarding of data, and thereby maximise the availability of quality long-term data.

Current PPBio activities in the Australasian region

The PPBio Australasia program began in 2006 and we have now initiated RAPELD grids with permanent plots at Karawatha Forest Park (KFP) in Brisbane, Lake Broadwater Conservation park in Dalby Shire, Queensland, Australia, and internationally at Chitwan

National Park in Nepal. Herein we briefly describe each of these initiatives to demonstrate the flexibility in the modular strategy used to collect systematic and comparable data within and among sites.

The first Australian PPBio site was established in collaboration with Brisbane City Council, South-east Queensland Catchments and the Nature Refuge Landholders Association in January 2007. The size and location of the reserve within an urban matrix necessitated a reduction in the standard 1km spacing of plots to 500m intervals resulting in 33 plots (Figure 5). Initial data analysis from the core vegetation surveys suggests there is

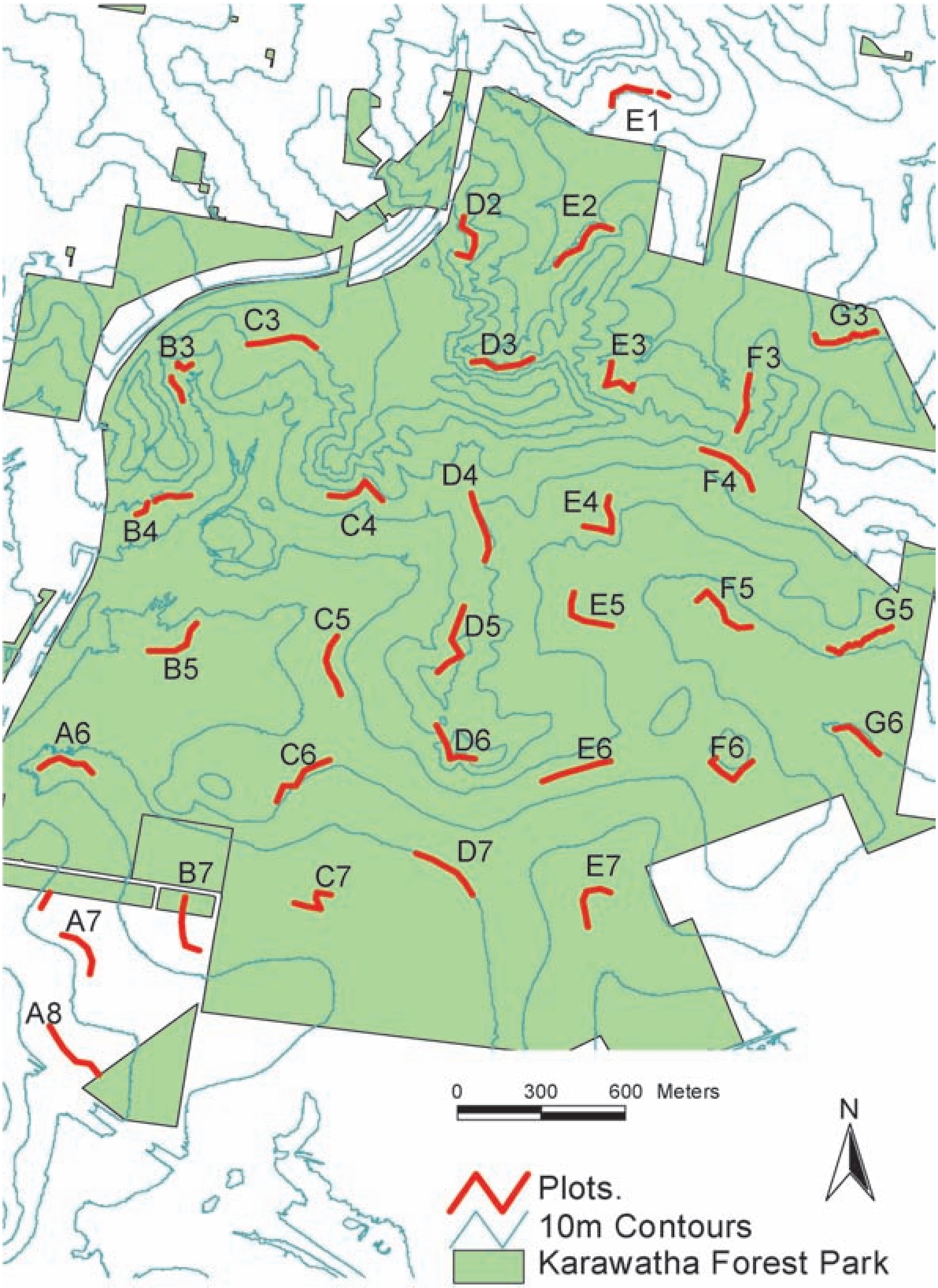
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Figure 5. Illustration of PPBio plot midlines following the contours of Karawatha Forest Park, Brisbane, QLD.

little spatial pseudoreplication even at this finer scale, and presents an ideal opportunity to examine the influence of scale on long-term ecological data sets. The first series of ecological baseline projects were initiated during 2007 and included assessments of soil characteristics, fire history, aspect, slope, vegetation structure and composition, and relative densities of reptiles, amphibians and birds. Although completed as a series of individual projects, the systematic and standardised nature of these surveys will enable us to examine the interactions allowing us to investigate ecosystem processes at the meso-scale (e.g. influence of fire on vegetation and reptile communities). Two PhD projects are now examining "Sustainable Indicators for Terrestrial Ecosystems" (SITEs including fauna, flora and abiotic indices) and "Predicting and Measuring the Impact of Climate Change on Frogs of South-east Queensland".

In September 2007, a second grid was established at Lake Broadwater, near Dalby in Southern Queensland. Here a 5 x 6 km grid was overlaid across the reserve to capture 19 plots at 1km intervals (Figure 1) including riparian Red Gum forest, Pilliga forest, Brigalow and grassland habitats. Five plots were established during an undergraduate "Conservation Biology" field trip and an additional 14 plots established in subsequent field trips. A core series of vegetation and fauna surveys have also been initiated.

In December 2007 we also initiated a PPBio - RAPELD grid in Chitwan National Park in southern Nepal in collaboration with World Wildlife Fund Nepal, the National Trust for Nature Conservation (NTNC), the Department of National Parks and Wildlife Conservation (DNPWC) and Tribhuvan University. Research is facilitated by local scientists (universities, institutes of higher education and research centres). At Chitwan, a standard RAPELD 5 x 5 km grid has been identified, and includes 30 plots at 1km spacing within riparian forest and grassland along the Rapti River floodplain, and in the Sal forest of the adjacent Churia Hills (Figure 6). The first 5 plots were established during a pilot study in December 2007.

The variation in the application of the PPBio grid and plot system demonstrates how the modular system can be flexible to suit the scale of the project and the physical constraints of the landscape. Despite changes in scale (reduced to 500m intervals at Karawatha) and the number of plots reduced to 19 at Lake Broadwater, the core elements of the program (e.g. 250m plots following the isoclines, replication of plots, etc) remain unchanged. This enables us to use the same sampling techniques (metadata and sampling protocols available on the internet site) and collect comparable relational data sets from all sites.

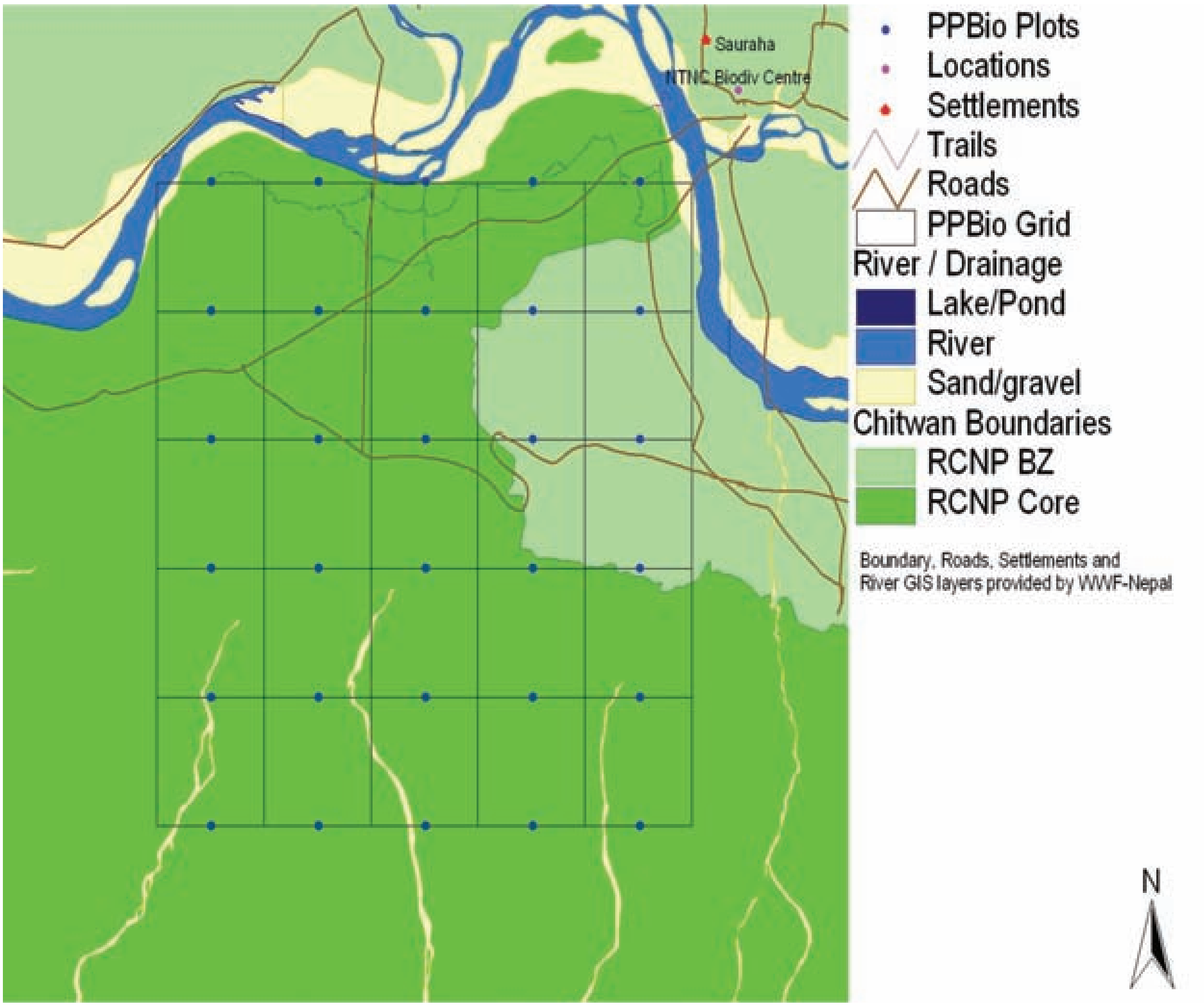

Figure 6. Location of PPBio RAPELD plots in Chitwan National Park, Nepal, with 30 plots at 1km intervals.

The PPBio Australasia vision

The aim of PPBio Australasia (as part of the international PPBio program) is to establish PPBio - RAPELD grids and/or modules in all of the major biogeographic regions throughout Australia. We are currently preparing three proposals to establish a network of RAPELD grids following longitudinal, latitudinal and altitudinal gradients in eastern Australia (Figure 7).

1. The first proposal includes a minimum of 8 RAPELD grids linked to the Great Eastern Ranges Initiative (formerly A2A Connectivity Conservation Project, Worboys 2007b) spanning from the Alps to Atherton to include climate refuge areas. These sites would include modules crossing the Great Dividing Range, with permanently marked plots at every 200m of elevation to detect potential biome shifts in response to climate change.
2. The second proposal includes a combination of PPBio - RAPELD grids and modules following an east - west longitudinal / rainfall gradient from Brisbane (existing Karawatha grid) extending westward into the arid region of central Australia to detect potential biome shifts in response to climate change.
3. The third proposal includes a minimum of 20 PPBio - RAPELD modules in coastal heath sites between Jervis Bay in NSW and Fraser Island in Queensland to monitor coastal systems in response to climate change. Within each site a minimum of 4 plots will be placed within waterbodies (coastal wetlands) with adjacent terrestrial plots to monitor terrestrial vegetation.

Implementing a network of PPBio - RAPELD grids throughout Australasia will allow us to measure Sustainable Indicators for Terrestrial Ecosystems (collected by local research organisations with an emphasis on involving postgraduate students from local tertiary institutions) that can provide long-term, comparable data that will be suitable for incorporating into State of the Environment Reporting at all levels of government (local, state and federal).

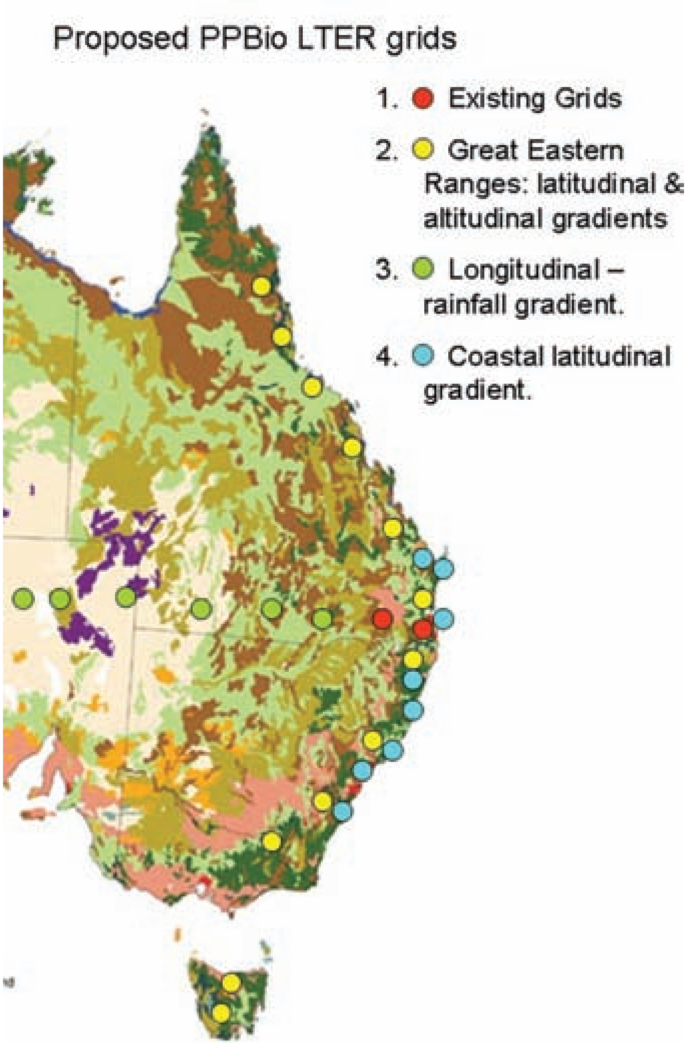
Proposed PPBio LTER grids
1. ● Existing Grids
2. ● Great Eastern Ranges: latitudinal & altitudinal gradients
3. ● Longitudinal – rainfall gradient.
4. ● Coastal latitudinal gradient.

Figure 7. Graphic representation of the vision for PPBio Australasia: to establish RAPELD LTER grids in major biogeographic regions throughout Australia.

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